DOCUMENT RESUME

ED 301 409 SE 050 103

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TITLE Computer-Assisted-Instruction: A Review of Research on the Effectiveness of CAI.
PUB DATE 88
NOTE 17p.
PUB TYPE Information Analyses (070)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS College Science; *Computer Assisted Instruction; Computer Oriented Programs; Computer Simulation; Computer Uses in Education; Elementary School Science; *Elementary Secondary Education; Higher Education; *Individualized Instruction; Instructional Effectiveness; *Microcomputers; *Programed Instructional Materials; Science Education; Science Instruction; *Secondary School Science; Teaching Methods

ABSTRACT

This reivew of research examines the effectiveness of computer-assisted-instruction (CAI) in raising the achievement levels of students at various levels and areas of instruction. The review studies four main categories of material written about CAI: (1) opinion papers; (2) descriptions of available hardware; (3) reports evaluating the effectiveness of CAI packages; and (4) guidelines and suggestions for authors of CAI software. It is suggested that CAI works best with low achievers and lower grade levels. At higher levels the novelty of computers is gone and no significant difference due to the use of CAI has been found over most other procedures. Contains 25 references. (ML)

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COMPUTER-ASSISTED-INSTRUCTION:

A REVIEW OF RESEARCH ON

THE EFFECTIVENESS OF CAI

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INTRODUCTION

Computers have been used as instructional tools for close to a quarter of a century. Computer-Assisted-Instruction (CAI) or Computer-Based-Education (CBE) became particularly common-place after Apple's introduction of its first microcomputer in 1978. School districts leaped onto the bandwagon of high technology in response to parental and community pressure to modernize elementary and secondary education. Tens of thousands of dollars have been spent in almost every school district in the country to furnish schools with Apples, Commodores, Ataris, TRS-80's, and now IBM's and IBM-compatibles. Software mills have been churning out interactive instructional programs to meet every need in K-12 and at the colleges and universities.

At this point in time, the reflective observer may justly ask the question, What improvement has the computer brought over previously-existing self-paced, programmed-instructional, or other audio-tutorial materials? Programmed instruction has been in existence for at least half a century. Has high technology in fact resulted in significantly higher achievement levels than those which resulted from paper-and-pencil exercises of the pre-computer age?

Just ten years ago, few children and few adults (outside of possible exposure in the latter's work environment) had any experience with computers. Video games were just beginning to

appear. Any contact children had with computers was novel and exciting. The feel of the keyboard, the sense of control over the computer and the fast response of the computer to commands all contributed to intense interest in computers and positive feedback from any use of computers in instruction. All that is passe now; computer-assisted-instructional software does not engage the attention that a video game can. Most CAI software is written in Basic, and interpretive Basic, at least, is the slowest of all programming languages. Thus, CAI software must be intrinsically more appealing than was once required if students are expected to be attentive to it and to benefit from it in terms of academic achievement levels that are attained.

A number of experimental studies have been conducted to assess the effectiveness of various CAI software packages. Many of these studies, especially those conducted relatively recently, tend to conclude that CAI does enhance achievement in the absence of any other programmed instructional materials, but that there is little, if any, statistical significance between achievement levels attained with CAI and achievement levels attained with paper-and-pencil supplemental materials.

Determining the relative effectiveness of a CAI software package over other available materials would seem desirable before committing large sums of money or the dedication of hardware resources to acquisition and utilization of the CAI package. For one thing, if current materials already being used work effectively in enhancing student achievement levels, why switch to something

new (just for the sake of something new)? For another, utilization of hardware may tie up that resource when it could be used more effectively for other purposes. No argument is made here against the usefulness of computers in academic settings, nor in the necessity of exposing students to a wide variety of applications of computers. However, the argument is being made that computers should not be tied up for purposes for which they are no more effective than other materials might be.

PURPOSE OF THE STUDY

This is a study to examine the relative effectiveness of computer-assisted-instruction in raising the achievement levels of students at various levels and areas of instruction. Current literature and research suggest that the effectiveness of CAI is in fact very questionable, so that evaluation of instructional software needs to be conducted for individual packages.

DEFINITIONS OF TERM

Basic: acronym for "Beginner's All-purpose Symbolic Instructional Code"; the most common language used to write programs.

Computer-Assisted-Instruction: the use of the computer as an aid in the teaching/learning process. Abbreviated "CAI."

Computer-Based-Education: alternate name for CAI. Abbreviated "CBE."

Drill-and-practice: exercises designed to help students practice some skill or concept that previously has been taught.

Graphics: the use of diagrams or other graphical means to obtain operating data and answers; the use of written symbols and visual displays.

Hardware: the various parts or devices which comprise the computer, e.g., keyboard, screen, diskdrives, printer.

Problem-solving: the four-step process of analyzing a problem, devising a procedure for solving the problem, using that procedure, and achieving a solution to the problem.

Simulation: the imitation of a real-world experience or situation.

Software: the sets of instructions that tell the computer what to do; programs.

Tutorial: an exercise in which the computer assumes responsibility for instruction in a lesson or series of lessons.

Word processing: the storage, manipulation, and processing of characters needed for the preparation of letters, reports, manuscripts, and other documents.

REVIEW OF THE LITERATURE

Many articles and books have been published on the subject of computer-assisted-instruction (CAI). They may be divided into four categories:

(a) Opinion papers written in favor of or against the use of CAI;

(b) Descriptions or critiques of available software, usually written to assist the reader in making decisions to purchase;

(c) Reports of research conducted to evaluate the effectiveness of CAI packages;

(d) Guidelines and suggestions for authors of CAI materials.

Articles in each of these four categories will be reviewed. Because of tremendous advances in both software and hardware in the past 20 years, the reader should assign more weight to opinions and conclusions expressed in more recent articles.

Castleberry (1970) wrote an early review of the benefits of CAI. He described four modes in which the computer can function: tutorial, remedial, drill-and-practice, and simulation. In particular, the computer should be capable of providing diagnostic instruction tailored to the needs of individual students. The "one-on-one" nature of the computer and the "patience" of the computer (the computer will wait forever, if necessary, for the student to respond) are important advantages of the computer over classroom instruction. Okey (1982) added that computers relieve human teachers of the burden of routine classroom testing and grading.

Wiebe (1983), however, began to voice more of the current attitude one finds in recent literature, namely that drill-and-practice does not make efficient use of the potential of the computer as a teaching machine. Drill can be done just as effectively with paper and pencil, especially at higher levels of education.

Schall (1986) presented a good overview of what kinds of activities are available for CAI. To the list of instructional

modes by Castleberry (1970), Schall added word processing and graphics.

Project SERAPHIM has been generating instructional software in chemistry for the past six years. Moore (1988) has been editing a series of articles reviewing new software available through SERAPHIM. The SERAPHIM project, funded by the National Science Foundation, and the series of articles in the Journal of Chemical Education are intended to provide a clearinghouse for CAI authors, to avoid duplication of efforts, and to make available newly-created software to chemical educators. In addition 1988 saw the introduction by SERAPHIM of a software journal in chemistry. Journal of Chemical Education: Software consists of actual diskettes containing user-ready software.

Bork (1978) described simulations that the Physics Computer Development Project developed in the field of physics. An example would be an exercise in gravitational motion. The article assists the reader in deciding whether or not to purchase the packages available, but there is no description of any research having been done to test the validity of the packages.

Okey (1985) suggestd that younger children are affected more favorably by CAI than older children, presumably because of the novelty still inherent in computers for younger children (and--this author would add--their lack of experience with video games). Okey suggested also that low achievers tend to benefit more from CAI than high achievers.

Vinsonhaler and Bass (1972) presented an early study of major studies that had been conducted to date in CAI drill-and-practice in math and language arts. They noted a substantial advantage in using CAI to augment traditional classroom instruction. At even this early date, however, they cautioned the limitation of the studies they had reviewed: no comparison had been made of CAI versus other modes of nonconventional instruction. They listed the following observations:

(a) Indications were that other, less expensive methods are just as effective as CAI;

(b) When computers were in their infancy, or when learners are very young themselves, there is a novelty effect to using computers, which wears off after a few years;

(c) Changes in the teacher's behavior may falsely contribute to the perceived effectiveness of CAI programs;

(d) Changes in the students' behavior may lead to false conclusions, e.g., the students may simply do more drill with the computer than they would do without it.

Castleberry et al (1973) reported that CAI was working very well. They acknowledged, however, that other types of supplemental or self-paced materials also worked very well. They felt that CAI is better adapted, though, for accomodating large numbers of students. In particular, a student can have one-to-one interaction anytime the computer lab is open, not just when an instructor or teaching assistant is available. (This author would point out the converse: with paper-and-pencil programmed materials, a student can

study anytime [whether or not the computer lab is open] and anywhere [at home or on the campus].)

Edwards et al (1975) reported conflicting results in their review of CAI programs. When CAI was substituted in whole or in part for traditional instruction, sometimes students improved, sometimes they did worse, and sometimes results were mixed. Results were especially inconclusive if the effectiveness of CAI was compared to other supplements, e.g., individual tutoring, language laboratories, and media such as programmed instruction and filmstrips. On the positive side, they did argue that CAI results in a reduction in time spent to achieve desired skills or knowledge. On the negative side, however, their review suggests that long-term retention may be less with CAI than with traditional instruction.

Cavin and Lagowski (1978) reported two beneficial uses of computers in instruction. In one, called "Computer Simulated Experiments," or "CSE," laboratory experiments were simulated on computers as an alternative or supplement to regular laboratory experiments. Students used the computers to analyze the data and report the results. In agreement with Okey (1985), their results indicated that CSE worked better with low-aptitude students than with high-aptitude students. In the other use, CAI was used successfully to teach the operation of laboratory instruments.

In a survey of 59 studies of CAI at the college level, Kulik, Kulik, and Cohen (1980) reported small but significant contributions towards course achievement and improvements in

students' attitudes toward instruction and in attitudes towards the subject matter. Their review supports the observation by Okey (1985) that the most remarkable results are attained in elementary schools, and that it is difficult to prove an advantage of CAI in higher education. As other studies have indicated, CAI seems to be as effective as other forms of supplemental instruction, but probably no more effective. This summary also supports the conclusions of Edwards et al (1975) that CAI reduces instructional time required, but that long-term retention is somewhat unfavorable. (Note: one might ask, Why does CAI reduce instructional time? This author cannot find any studies in which anyone has attempted to answer that question.)

Cavin, Cavin, and Lagowski (1981) looked at the effects of CAI on students' attitudes towards using computers and towards the subject of chemistry. Males demonstrated no improvement towards computers, presumably because they entered the studies already favorable towards computers. CAI did appear to improve the attitudes of females towards computers. Neither group demonstrated any improvement in attitude towards chemistry. The authors remarked that pre-1980 studies did show improvement in attitudes towards subject matter (again, possibly because of the novelty of computers in the 1970's).

McKenzie and Karnau (1985) reported a recent study conducted in the lab section of a general science course for elementary school teachers. An experimental group was given a multiple-choice, computer-based diagnostic test in preparation of a teacher-

made final exam. The control group was not given the diagnostic test. Although the experimental group believed that the test had helped them to prepare better for the final exam, there was no significant difference in the results of the two groups.

Wainwright (1985) reported an experimental study of CAI in a high school chemistry course. The experimental group received supplemental computerized exercises; the control group used paper-and-pencil worksheets. Wainwright found that the control group achieved higher scores than the experimental group. Females demonstrated no preference for computers, and, in fact, showed a more favorable attitude towards chemistry in the control group. Males, as expected, preferred using the computers, but demonstrated no improvement in attitude towards chemistry in either group.

Howard (1986) attempted to assess the impact of personality characteristics and attitudes on learning by CAI. She observed no significant difference between the experimental and control groups on achievement, retention, or attitude.

Dinkins (1986) developed a CAI courseware package in statistics for graduate students. Although he observed that the students did learn the statistical concepts, he made no mention of having used a control group that did not receive CAI as a means for comparison.

The effectiveness of CAI with Chapter I students in secondary schools was studied by Davidson (1986). The experimental group worked on computers; the control group did not. Davidson reported no significant difference in mathematics achievement with the

experimental group.

The improvement of problem-solving performance was reported by Melnik (1986). The experimental group had experience on microcomputers with problem-solving software. The control group received supplemental teacher-directed instruction with work-sheets. Melnik reported that both groups increased in ability, supporting Castleberry et al (1973) and Edwards et al (1975) that other modes of supplemental instruction are just as effective as CAI.

Dalton (1986) conducted a study of computer-assisted-instruction with four groups: total CAI; 2/3 CAI and 1/3 conventional instruction; 1/3 CAI and 2/3 conventional; all conventional instruction. Instruction lasted for 10 days and a retention study was conducted 17 weeks later. It was concluded that the more CAI, the better, but no comparison was made with other forms of supplemental exercises.

The literature suggests that a major obstacle in providing more effective computer-assisted-instruction is the lack of good software. In the early years of CAI, the deficiencies of poor software were offset by the novelty of computers and the intense interest of children in working on the "new" machines. CAI software has certainly improved over the years, but perhaps not enough--especially for older students--to compensate for the decline in interest now that the novelty has worn off. Thus, current papers appearing in the literature contain guidelines for writers of CAI software, no longer just in terms of "how to

program", but which apply educational principles of learning theory to CAI programs.

Smith and Boyce (1984) lamented the unavailability and poor quality of software. They suggested several guidelines for the writing of effective CAI materials.

Guidelines tend to be patterned on the work of Gagne et al (1981), which provides step-by-step "events of instruction" that a CAI lesson should follow. Gagne offers the following steps:

> The student views some information and is then asked a question. Positive reinforcement or negative feedback is given to the student's response. If the student's response is incorrect, the student is told why and given another opportunity to respond to the same question.

The program may then branch to a remedial sequence before returning to the main program. In the event that a student demonstrates good prior knowledge of the material, the program would skip the next few frames.

The "Events of Instruction," as Gagne calls them, are the following:

1. Gaining Attention
2. Informing Learner of Lesson Objective
3. Stimulating Recall of Prior Learning
4. Presenting Stimuli with Distinctive Features
5. Guiding Learning
6. Eliciting Performance
7. Providing Informative Feedback
8. Assessing Performance
9. Enhancing Retention and Learning Transfer

In addition to these suggestions providing useful guidelines for authors, it would seem reasonable also that they would be useful guidelines to use in the evaluation of a software package. As

Gagne (1977) pointed out elsewhere, these guidelines can be applied to a variety of desired learning outcomes, including recall of verbal information, intellectual skills, cognitive strategies, motor skills, and development of attitudes.

CONCLUSIONS

In summary, one concludes that a tremendous amount of effort and expense has gone into the creation, utilization, and evaluation of computer-assisted-instructional software packages. Although the earliest feedback from CAI usage tended to be very favorable, the literature suggests that the best results even then were obtained with elementary school children, or when CAI was compared to conventional instruction supplemented with no other nontraditional methods. At higher levels of education, as the novelty of using computers has tended to wear off, research has generally failed to detect any significant difference between achievement levels attained by students using CAI and students using more conventional paper-and-pencil self-paced, auto-tutorial, or programmed instructional materials.

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